Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 44 (2012) 826 – 829

Procedia Engineering

www.elsevier.com/locate/procedia

Euromembrane Conference 2012

[P1.065]

Influence of the ionic composition on the demineralisation of saccharide solutions by electrodialysis

S. Galier*[1,2], M. Courtin[1,2], H. Roux-de Balmann[1,2]

[1]Université de Toulouse, France, [2]CNRS, France

Efficient processes, like membrane operations, and especially electrodialysis, are required for the treatment of complex fluids containing variable quantities of organic and mineral species, to fit with environmental regulations as well as product quality constraints. This is specially the case in the food industry (production of organic acids, sugar industry, milk products…) as well as for environmental concerns (treatment of waste waters, lixiviates or brines,..).

In the case of demineralization of saccharide solutions by electrodialysis, the process efficiency is characterized by the saccharide loss, which has to be kept as low as possible, and the demineralization factor, which can reach quite high values. However, it was demonstrated that both parameters are linked and that the relationship between them depends on the ionic composition. For instance, it was reported during the demineralization of acetic acid solutions at different salt compositions, that the organic matter loss, fixed by the diffusion of the acetic acid through the ion-exchange membranes, was more important in presence of sodium sulfate or calcium chloride than with sodium chloride [1]. It was further shown that the modification of the organic solute transfer comes from the combination of two different contributions. On one hand, according to the ionic composition of the solution, the membrane “free volume” can change (swelling phenomenon) [2;3]. It was also demonstrated that the solute size can vary because of its dehydration in presence of electrolyte [4].

The aim of the present work was then to investigate the influence of the ionic composition on the demineralization of a saccharide solution containing glucose.

Laboratory pilot scale experiments were carried out in order to evaluate the influence of the ionic composition on the water and solutes fluxes (glucose and salts) through the membrane under different conditions (ionic compositions, with or without current). From these values, the variation of the glucose loss factor versus the demineralisation factor was calculated in order to evaluate the impact of the ionic composition on the process performances.

Experiments were performed in a batch mode with an electrodialysis stack (EUR-2B-10), supplied by Eurodia Industrie, equipped with AMX and CMX ion exchange membranes (Neosepta, Tokuyama corp., Japan). A glucose solution, containing different salt (NaCl, Na_2SO_4 and $CaCl_2$) was used. Glucose and salt concentrations were fixed at 1M and 1éq.L^{-1} respectively.

The water and salt fluxes were first investigated.

From experiments carried out without current (I=0) it was shown that, as expected from previous works [5;6], the contribution of osmosis to the solvent flux as well as that of diffusion to the salt flux were negligible compared to that coming from electroosmosis and migration, obtained under normal ED conditions (I≠0).

doi:10.1016/j.proeng.2012.08.587

Moreover, it was found that the water (electroosmotic) and salt fluxes were proportional to the electric current. Whilst both fluxes could depend on the salt composition, the variations of the values obtained with the different electrolytes were small (lesser than 6%) so that no tendency was drawn.

Then the transfer of glucose was considered as function of the salt composition.

From diffusion experiments, it was shown that, the glucose diffusion flux, $J_{G\ diff}$, as well as the water osmotic flux, Jos, depends on the salt composition. Both fluxes were found to vary according to the following sequence: flux in NaCl > flux in $CaCl_2$ > flux in Na_2SO_4.

These results can be correlated to the hydration scale of the ions. Indeed, Cl- is less hydrated than SO42- and Na+ is less hydrated than Ca2+ [7]. Then, for a fixed cation, Na+ in our conditions, the less the anion hydration, the highest the water and glucose transfer. In the same manner, for a fixed anion, Cl-, the less the cation hydration, the highest the water and glucose transfer.

These results are in agreement with those obtained in a previous work showing that the transfer modification reflects changes in the membrane properties associated with the hydration of the counter-ion which is likely linked to swelling mechanisms at a microscopic scale [8].

From the experiments carried out in normal ED conditions, the variation of the glucose flux, in presence of various electrolytes, versus the electrical current is represented in Fig. 1. The diffusion fluxes (values at I=0) are also reported. One can observe that the flux varies linearly with the current. Then, the transfer of glucose under ED conditions is the sum of two contributions: diffusion and convection, due to the electroosmotic water flux which, as previously discussed, is proportional to the electrical current.

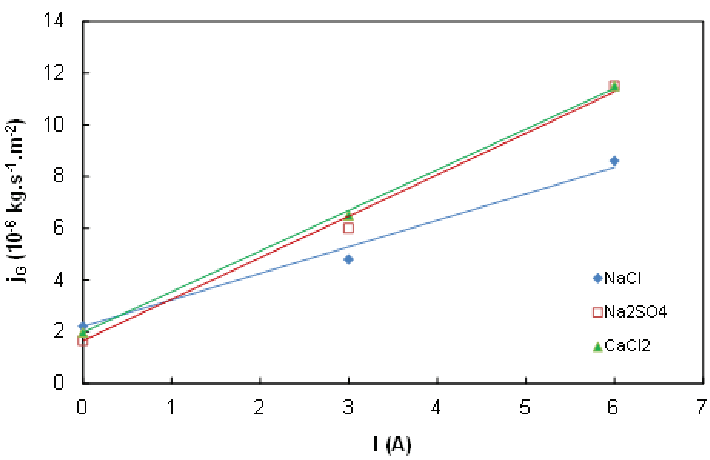

Fig. 1. Variation of the glucose flux versus the electrical current: influence of the electrolyte nature – [Glucose] = 1 mol L^{-1}; [Electrolyte] = 1eq L^{-1}

The values of the slopes are 1.03; 1.51 and 1.62 for NaCl, $CaCl_2$ and Na_2SO_4, respectively. It is important to note that this value characterizes the convective contribution to the glucose flux and for a given current, increasing values reflect increasing glucose convection fluxes. Then, as previously discussed for diffusion experiments, these variations can be correlated to the hydration scale of ions. However, the influence of the ion hydration on the convection flux is different since for a fixed cation (or anion) increasing values, i.e. increasing convection fluxes, are obtained for decreasing anion (or cation) hydration.

These results can be explained from a previous study which has investigated the influence of the ionic composition on the mass transfer of saccharides through a Nanofiltration membrane [10]. In this case, it was shown that the saccharide transfer increases in presence of salts and that this increase was correlated to the saccharide dehydration in presence of electrolyte. More precisely, more hydrated ions and increasing electrolyte concentrations were found to increase the saccharide dehydration and then the saccharide transfer through the membrane.

Finally, the water, salt and glucose fluxes enables to calculate the glucose loss factor versus the demineralisation factor to evaluate the influence of the electrolyte nature on the process performances (Fig. 2). It was observed that, for a fixed demineralisation factor, the neutral solute loss factor increased with the ion hydration. As previously discussed, this is due to the higher contribution of the glucose convection flux, mainly governed by the neutral solute dehydration in presence of electrolyte, compared to the diffusion one, mainly fixed by the membrane properties modification.

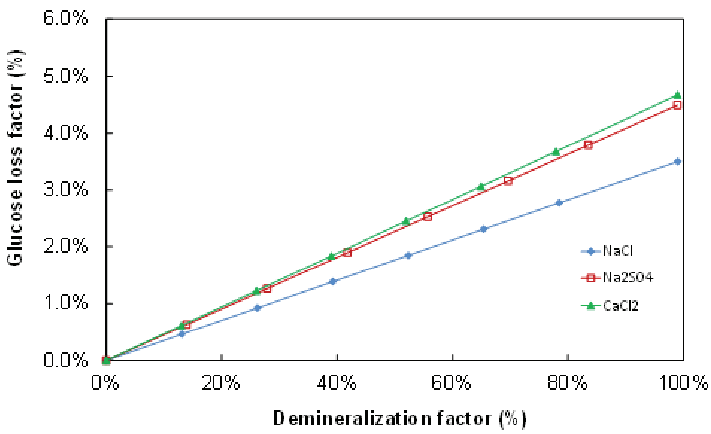

Fig. 2. Glucose loss factor versus the demineralization factor: influence of the electrolyte nature – I = 6 A; [Glucose] = 1 mol L^{-1}; [Electrolyte] = 1eq L^{-1}

[1]E. Singlande, H. Roux-de Balmann, X. Lefevbre, M. Sperandio, Improvement of the treatment of salted liquid waste by integrated electrodialysis upstream biological treatment, Desalination 199 (2006) 64-66.

[2]X.-L. Wang, C. Zhang, P. Ouyang, The possibility of separating saccharides from a NaCl solution by using nanofiltration in diafiltration mode, J. Membr. Sci. 204 (2002) 271-281.

[3]G. Bargeman, J.M. Vollenbroek, J. Straatsma, C.G.P.H. Schroën, R.M. Boom, Nanofiltration of multi-component feeds. Interactions between neutral and charged components and their effect on retention, J. Membr. Sci. 247 (2005) 11-20.

[4]A. Bouchoux, H. Roux-de Balmann, F. Lutin, Nanofiltration of glucose and sodium lactate solutions: variations of retention between single- and mixed-solute solutions, J. Membr. Sci. 258 (2005) 123-132.

[5]M. Bailly, H. Roux-de Balmann, P. Aimar, F. Lutin, M. Cheryan, Production processes of fermentaed organic acids targeted around membrane operations: design of concentration step by electrodialysis, J. Membr. Sci. 191 (2001) 129-142

[6]F.J. Borges,H. Roux-de Balmann, R. Guardani, Investigation of the mass transfer processes during the desalination of water containing phenol and sodium chlorie by electrodialysis, J. Membr. Sci. 325 (2008) 130-138.

[7]Y. Marcus, Ion properties, Marcel Decker, Inc, New York, N.Y, (1997).

[8]J. Savignac, S. Galier, H. Roux de Balmann, Interactions between polymeric ion exchange membrane materials and sugar/electrolyte solutions – Impact on the mass transfer, MATBIM 2010, Paris 2010.

[9]V. Boy, H. Roux-de Balmann, S. Galier, Relationship between volumetric properties and mass transfer through NF membrane for saccharide/electrolyte systems, J. Membr. Sci. 390-391 (2012) 254-262.

Keywords: saccharide, electrodialysis, mass transfer, hydration